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ORIGINAL RESEARCH ARTICLE

Evaluation of ecological civilization city construction level in Longnan area based on entropy weight TOPSIS model

Jingchuan Zhang*, Hongyu Liu

Longnan Normal College of Higher Education, Chengxian 742500, Gansu, China. E-mail: zjc-1281@163.com

ABSTRACT

This paper selects 13 evaluation indexes of ecological civilization city construction level in 9 counties of Longnan City, processes the index data by using entropy weight TOPSIS method, calculates the closeness of ecological civilization city construction level in each county, makes an overall ranking of ecological civilization city construction level in each county, and then analyzes the ranking results, in order to provide theoretical guidance for ecological civilization construction in Longnan City.

Keywords: ecological civilization city construction; evaluation index system; entropy weight; TOPSIS

1. Introduction

In recent years, with the gradual deepening of industrialization and the development of economy and society, the urbanization rate of China's permanent population has reached 58.52% by the end of 2017. Urban agglomeration will become the main form of future society. About 70% of the country's population has actually entered cities and their surrounding areas, urban ecological problems have seriously deteriorated, and disharmonious factors between cities and nature will increase year by year. How to balance the relationship between resources, environment and economic development has become an urgent problem for provincial and municipal governments. Therefore, scientific and reasonable evaluation of the construction level of ecological civilization city in Longnan City has very important theoretical and practical significance for the development of Longnan City entropy weight. TOPSIS model is a commonly used multi-objective decision-making analysis method of limited scheme. Through calculation, the relative closeness between each object to be evaluated and the ideal point is taken as the basis for evaluating each object[1]. This model is applied to analyze the evaluation of the construction level of ecological civilization city in Longnan City, reflecting the local and overall characteristics of economic, social, resource and environmental protection of urban ecological civilization construction in Longnan area realize the harmonious coexistence and sustainable development between man and nature.

2. Construction of evaluation index system of sustainable development ability

Building ecological civilization is a huge and

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complex systematic project, involving many disciplines and covering a wide range of contents. Based on the collection and retrieval of domestic and foreign scholars' literature on the construction of ecological civilization city in recent years by using many ways such as China hownet, Google academic network and school library, according to the five principles of index construction (scientificity, representativeness, operability, comprehensiveness and importance) and combined with the actual development of Longnan City, an index system suitable for evaluating the construction level of ecological civilization in Longnan City is obtained. Three secondary index systems are constructed from three perspectives (economic sustainable development capacity, social mechanism construction, ecological construction and environmental protection), as listed in **Table 1**, trying to be more objective and comprehensive to approach the reality of ecological civilization construction in Longnan area[2,3].

The original data comes from the 2015 data of Longnan City in the 2016 Gansu Yearbook and the statistical bulletin of national economic and social development of Longnan City. Some data can be obtained directly, and some can be calculated Excel software is used to realize the algorithm of the model, which makes the calculation result of the model simpler and more accurate.

Table 1. Three level evaluation index system of ecological civilization city construction level

Level I index (target layer P)	Level II index (standard test R)	Level III indicator (indicator level C)
Index system of ecological civilization city construction level	Economic sustainable development capacity	GDP (RMB 100 million) x_1
		Added value of tertiary industry (RMB 100 million) x_2
		Added value of industries above Designated Size (RMB 100 million) x_3
		Total investment in fixed assets (RMB 100 million) x_4
	Social mechanism construction	Annual comprehensive tourism income (RMB 100 million) x_5
		Total retail sales of social consumer goods (RMB 10,000) x_6
		Per capita disposable income of farmers (thousand yuan) x_7
		Per capita disposable income of urban residents (thousand yuan) x_8
	Ecological construction and environmental protection	Annual grain planting area (10,000 mu) x_9
		Total annual grain output (10,000 tons) x_{10}
		Natural population growth rate (‰) x_{11}
		Forest coverage (%) x_{12}
		Centralized urban sewage treatment rate (%) x_{13}

3. TOPSIS method of entropy weight

TOPSIS method based on entropy weight is divided into the following five steps.

(1) Primitive matrix standardization.

In this paper, there are n objects to be evaluated (prefecture level cities), and each evaluation object has m evaluation indexes to form the original data matrix.

$$\boldsymbol{X}=\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{pmatrix} \tag{1}$$

Normalize the original data matrix X to obtain matrix R,

$$\boldsymbol{R}=(r_{ij})_{n\times m},$$
$$i=1,2,\cdots,n;j=1,2,\cdots,m, \tag{2}$$

Where, r_{ij} is the standard value of the *i*-th evaluation object on the *j*-th evaluation index, *ij* $\in$ [0,1].

Positive index.

$$r_{ij} = \frac{x_{ij} - \lim_{i}\{x_{ij}\}}{\lim_{i}\{x_{ij}\} - \lim_{i}\{x_{ij}\}}.$$

(3)

Reverse index.

$$r_{ij} = \frac{\max_{i}\{x_{ij}\} - x_{ij}}{\max_{i}\{x_{ij}\} - \min_{i}\{x_{ij}\}}.$$

(4)

(2) Construction of standardized weighting matrix Z based on “entropy weight method”.

Define f_{ij} as the proportion of the index value under the *j* evaluation index of the *i*-th evaluated object of matrix *R*, then:

$$f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}}.$$

Let e_j be the entropy of the *j*-th index, then:

$$e_j = -k\sum_{i=1}^{n} f_{ij}\ln f_{ij}, k = \frac{1}{\ln n}.$$

When f_{ij} = 0, take f_{ij} = 0.000001 instead of the weight of each evaluation index.

$$\omega_j = \frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)},$$
$$0 \leqslant \omega \leqslant 1, \sum_{j=1}^{m}\omega_j = 1.$$

(5)

Construct normalized weighting matrix.

$$\boldsymbol{Z} = \omega_j \cdot \boldsymbol{R}$$

(6)

(3) Determine positive ideal solution and negative ideal solution.

Let *J* represent the positive indicator set and *J’* represent the negative indicator set, then the positive ideal solution:

$$Z^{+} = \{(\max_{i} Z_{ij} \mid i \in J),$$
$$(\min_{i} Z_{ij} \mid i \in J'),$$
$$i = 1,2,\cdots,n\} = \{Z_1^{+}, Z_2^{+}, \cdots, Z_m^{+}\};$$

(7)

Negative ideal solution:

$$Z^{-} = \{(\min_{i} Z_{ij} \mid i \in J),$$
$$(\max_{i} Z_{ij} \mid i \in J'),$$
$$i = 1,2,\cdots,n\} = \{Z_1^{-}, Z_2^{-}, \cdots, Z_m^{-}\}.$$

(8)

(4) Euclidean distance calculation.

Calculate the distance from each evaluation object to the positive ideal S_i^{+} solution and to the negative ideal solution S_i^{-}.

$$S_i^{+} = \sqrt{\sum_{j=1}^{m}(Z_{ij} - Z_j^{+})^2},$$
$$i = 1,2,\cdots,n;$$

(9)

$$S_i^{-} = \sqrt{\sum_{j=1}^{m}(Z_{ij} - Z_j^{-})^2},$$
$$i = 1,2,\cdots,n.$$

(10)

(5) Calculate closeness.

Calculate the relative closeness of each evaluation object close to the positive ideal solution C_i^{+}.

$$C_i^+ = \frac{s_i^-}{S_i^+ + S_i^-} 0 \leqslant C_i^+ \leqslant 1,$$
$$i = 1, 2, \cdots, n.$$

(11)

The larger C_i^+ is, the closer it is to the ideal solution, which means that the city has strong competitiveness.

4. Empirical analysis on comprehensive evaluation of ecological civilization city construction level

4.1. Calculation process

Firstly, find out the maximum and minimum values of each index corresponding to 9 counties, subtract the minimum value from the maximum value to calculate the positive index, and then gradually process the data of each county according to the calculation formula of TOPSIS method[4,5]. The statistical data of ecological civilization city construction level indicators of each County in Longnan City in 2015 are listed in **Table 2**.

Table 2. Statistical data of ecological civilization city construction level indicators of counties in Longnan City in 2015

Index	Cheng County	Hui County	Wen County	Liangdang	Wudu	Xihe	Dangchang	Kang County	Li County
GDP/RMB 100 million	51.13	42.06	23.58	6.61	93.55	30.43	21.16	20.68	30.96
Added value of tertiary industry/RMB 100 million	24.24	18.85	11.93	3.69	63.82	16.9	11.68	10.29	15.26
Added value of industries above Designated Size/RMB 100 million	10.88	6.11	19.96	0.24	3.73	4.9	2.18	4.78	5.06
Investment in fixed assets/RMB 100 million	80.65	58.6	74.71	10.2	102.61	67.82	61.05	74.89	64.11
Annual comprehensive tourism income/RMB 100 million	6.4	5.8	1.98	2.2	33.36	3	9.8	10.34	5.05
Retail sales of social consumer goods/RMB 100 million	9.03	6.12	6.3	2.02	35.84	6.36	6.73	5.84	14.3
Per capita disposable income of farmers/RMB 1,000	6.494	7.084	4.962	4.973	5.656	4.974	4.83	5.455	2.528
Urban per capita disposable income/RMB 1,000	18.9484	20.744	18.1951	19.443	19.768	18.129	18.016	19.756	19.689
Annual grain planting area/km^2	329.07	365.54	245.33	8.93	546.80	455.60	184.80	304.53	482.87
Total annual grain output/10,000 tons	14.245	16.03	6.78	3.813	16.54	19.57	8.27	7.44	18.75
Natural population growth rate/‰	6.08	3.82	4.5	-0.78	6.2	6.27	4.72	4.11	4.3
Forest coverage/%	43.5	46	61.5	74.1	29.82	38.08	54.2	67.64	45
Centralized urban sewage treatment rate/%	32	31.1	43	34	95	56	65.3	38	54

Normalize the original data matrix *X* to obtain matrix *R*.

$$\boldsymbol{R} = (r_{ij})_{n\times m},$$
$$i = 1, 2, \cdots, n, j = 1, 2, \cdots, m.$$

(12)

Where, r_{ij} is the standard value of the *i*-th evaluation object on the j-th evaluation index, *ij* $\in$ [0,1].

Take positive index.

$$r_{ij} = \frac{x_{ij} - \lim\limits_{i}\{x_{ij}\}}{\lim\limits_{i}\{x_{ij}\} - \lim\limits_{i}\{x_{ij}\}},$$

(13)

The data of standardized matrix *R* are listed in **Table 3**.

Table 3. Data of matrix *R* obtained by standardizing the original data matrix *X*

Index	Cheng County	Hui County	Wen County	Liangdang	Wudu	Xihe	Dangchang	Kang County	Li County
GDP/RMB 100 million	0.5121	0.4078	0.1952	0.0000	1.0000	0.2740	0.1674	0.1618	0.2801
Added value of tertiary industry/RMB 100 million	0.3418	0.2521	0.1370	0.0000	1.0000	0.2197	0.1329	0.1098	0.1924
Added value of industries above designated size/RMB 100 million	0.5396	0.2977	1.0000	0.0000	0.1770	0.2363	0.0984	0.2302	0.2444
Investment in fixed assets/RMB 100 million	0.7624	0.5238	0.6981	0.0000	1.0000	0.6235	0.5503	0.7000	0.5834
Annual comprehensive tourism income/RMB 100 million	0.1409	0.1217	0.0000	0.0070	1.0000	0.0325	0.2492	0.2664	0.0978
Retail sales of social consumer goods/RMB 100 million	0.2073	0.1212	0.1266	0.0000	1.0000	0.1283	0.1393	0.1130	0.3631
Per capita disposable income of farmers/RMB 1,000	0.8705	1.0000	0.5342	0.5367	0.6866	0.5369	0.5053	0.6424	0.0000
Urban per capita disposable income/RMB 1,000	0.3418	1.0000	0.0657	0.5231	0.6422	0.0414	0.0000	0.6378	0.6133
Annual grain planting area/km^2	0.5952	0.6630	0.4395	0.0000	1.0000	0.8304	0.3270	0.5496	0.8811
Total annual grain output/10,000 tons	0.6621	0.7753	0.1883	0.0000	0.8077	1.0000	0.2829	0.2302	0.9480
Natural population growth rate/‰	0.9730	0.6525	0.7489	0.0000	0.9901	1.0000	0.7801	0.6936	0.7206
Forest coverage/%	0.3089	0.3654	0.7154	1.0000	0.0000	0.1865	0.5506	0.8541	0.3428
Centralized urban sewage treatment rate/%	0.0141	0.0000	0.1862	0.0454	1.0000	0.3897	0.5352	0.1080	0.3584

e_j = (0.853796, 0.805391, 0.835343, 0.936912, 0.890763, 0.677083, 0.77169, 0.93236, 0.837599, 0.921632, 0.881148, 0.940317, 0.888857, 0.755983), ω_j = (0.070592, 0.093963, 0.079501, 0.030461, 0.052743, 0.155914, 0.110235, 0.032659, 0.078412, 0.037838, 0.057385, 0.028817, 0.053663, 0.117818).

The weight of each evaluation index.

$$\omega_j = \frac{1 - e_j}{\sum_{j=1}^{m} (1 - e_j)},$$

$$0 \leqslant \omega \leqslant 1, \ \sum_{j=1}^{m} \omega_j = 1, \tag{14}$$

The normalized weighting matrix is constructed $\boldsymbol{Z} = \omega_j \cdot \boldsymbol{R}$, the results are listed in **Table 4**.

The maximum, minimum, entropy, weight and Euclidean distance of positive ideal solution and negative ideal solution of each index are listed in **Table 5.**

The Euclidean distance and closeness of each evaluation object calculated according to TOPSIS method are as follows.

$$S_i^+ = \begin{pmatrix} 0.236399 \\ 0.244451 \\ 0.261083 \\ 0.292966 \\ 0.095448 \\ 0.251605 \\ 0.237227 \\ 0.239198 \\ 0.226082 \end{pmatrix}, \quad S_i^- = \begin{pmatrix} 0.106945 \\ 0.12177 \\ 0.108012 \\ 0.07389 \\ 0.284667 \\ 0.102224 \\ 0.096907 \\ 0.100803 \\ 0.116515 \end{pmatrix}, C_i^+ = \begin{pmatrix} 0.31148 \\ 0.332504 \\ 0.29264 \\ 0.201415 \\ 0.748898 \\ 0.288907 \\ 0.290023 \\ 0.296477 \\ 0.340094 \end{pmatrix}, \tag{15}$$

Table 4. Data after forming normalized weighting matrix

Index	Cheng County	Hui County	Wen County	Liangdang	Wudu	Xihe	Dangchang	Kang County	Li County
GDP/100 million yuan	0.0382	0.0304	0.0145	0.0000	0.0745	0.0204	0.0125	0.0121	0.0209
Added value of tertiary industry/RMB 100 million	0.0339	0.0250	0.0136	0.0000	0.0992	0.0218	0.0132	0.0109	0.0191
Added value of industries above Designated Size/RMB 100 million	0.0453	0.0250	0.0839	0.0000	0.0149	0.0198	0.0083	0.0193	0.0205
Investment in fixed assets/RMB 100 million	0.0245	0.0168	0.0224	0.0000	0.0322	0.0201	0.0177	0.0225	0.0188
Annual comprehensive tourism income/RMB 100 million	0.0232	0.0200	0.0000	0.0012	0.1646	0.0054	0.0410	0.0439	0.0161
Retail sales of social consumer goods/RMB 100 million	0.0241	0.0141	0.0147	0.0000	0.1164	0.0149	0.0162	0.0131	0.0423
Per capita disposable income of farmers/RMB 1,000	0.0300	0.0345	0.0184	0.0185	0.0237	0.0185	0.0174	0.0221	0.0000
Urban per capita disposable income/ RMB 1,000	0.0283	0.0828	0.0054	0.0433	0.0532	0.0034	0.0000	0.0528	0.0508
Annual grain planting area/km^2	0.0238	0.0265	0.0176	0.0000	0.0399	0.0332	0.0131	0.0220	0.0352
Total annual grain output/10,000 tons	0.0401	0.0470	0.0114	0.0000	0.0489	0.0606	0.0171	0.0139	0.0574
Natural population growth rate/‰	0.0296	0.0198	0.0228	0.0000	0.0301	0.0304	0.0237	0.0211	0.0219
Forest coverage/%	0.0175	0.0207	0.0405	0.0567	0.0000	0.0106	0.0312	0.0484	0.0194
Centralized urban sewage treatment rate/%	0.0018	0.0000	0.0232	0.0056	0.1244	0.0485	0.0666	0.0134	0.0446

Table 5. Maximum, minimum, entropy, weight and euclidean distance of positive ideal solution and negative ideal solution of each index

Indicators	Maximum	Minimum value	Entropy EJ	Weight WJ	Positive ideal solution Z_j^+	Negative ideal solution Z_j^-
GDP/RMB 100 million	93.55	6.61	0.8538	0.0745	0.0745	0.0000
Added value of tertiary industry/RMB 100 million	63.82	3.69	0.8054	0.0992	0.0992	0.0000
Added value of industries above designated size/RMB 100 million	19.96	0.24	0.8353	0.0839	0.0839	0.0000

Table 5. (*Continued*)

Indicators	Maximum	Minimum value	Entropy EJ	Weight WJ	Positive ideal solution Z_j^+	Negative ideal solution Z_j^-
Investment in fixed assets/RMB 100 million	102.61	10.2	0.9369	0.0322	0.0322	0.0000
Annual comprehensive tourism income/RMB 100 million	33.36	1.98	0.6771	0.1646	0.1646	0.0000
Retail sales of social consumer goods/RMB 100 million	35.84	2.02	0.7717	0.1164	0.1164	0.0000
Per capita disposable income of farmers/RMB 1,000	7.084	2.528	0.9324	0.0345	0.0345	0.0000
Urban per capita disposable income/ RMB 1,000	20.744	18.016	0.8376	0.0828	0.0828	0.0000
Annual grain planting area/km^2	546.80	8.93	0.9216	0.0399	0.0399	0.0000
Total annual grain output/10000 tons	19.57	3.813	0.8811	0.0606	0.0606	0.0000
Natural population growth rate/‰	6.27	-0.78	0.9403	0.0304	0.0304	0.0000
Forest coverage /%	74.1	29.82	0.8889	0.0567	0.0567	0.0000
Centralized urban sewage treatment rate /%	95	31.1	0.7560	0.1244	0.1244	0.0000

The data of each evaluation index is processed step by step according to the calculation formula of TOPSIS method. Calculate the closeness of each evaluation index to the construction level of ecological civilization city, and rank the construction level of ecological civilization city in each county. The results are listed in **Table 6**.

Table 6. Ranking of ecological civilization city construction level of counties in Longnan City in 2015

City	Closeness	Ranking	City	Closeness	Ranking
Cheng County	0.31148	4	Xihe	0.288907	8
Hui County	0.332504	3	Dangchang	0.290023	7
Wen County	029264	6	Kang County	0.296477	5
Liangdang	0.201415	9	Li County	0.340094	2
Wudu	0.748898	1			

4.2. Result analysis

From the ranking in **Table 6**, according to the evaluation value of the construction level C_i^+ of ecological civilized cities in each county of Longnan City, the construction level of ecological civilized cities in nine main counties of Longnan City is ranked. The larger C_i^+ is, the stronger the construction level of ecological civilized cities in the county is; the smaller C_i^+ is, the weeker the construction level. The comprehensive strength evaluation results of the construction level of these 9 counties basically conincides with the actual situation. Wudu District ranks first in the level of ecological civilization city construction, Li County ranks second in the level of ecological civilization city construction, Huixian county ranks third in the level of ecological civilization city construction, and Cheng County ranks fourth in the level of ecological civilization city construction. In 2015, the GDP of Wudu District reached RMB 9.355 billion. Projects such as returning farmland to forest and grassland and natural forest protection were implemented to create 92 km^2 of ecological forest, 267.3 km^2 of economic forest, 91,274 km^2 of natural forest management and protection area, 409.54 km^2 of key public welfare forest management and protection, 29.82% of forest coverage and 95% of harmless treatment rate of urban domestic waste. The total area of Li County is 4,263.58 km^2, the cultivated land area is 688.20 km^2, the frost-free period is 208 days, the annual precipitation is 454.8 mm, and the total amount of water resources is 1.08 billion m^3. The newly developed Apple area is 16 km^2, walnut area is 51.33 km^2 and pepper area is 3.33 km^2, accumulating to 391.60 km^2, 277.33 km^2 and 84 km^2 respectively. There is one nature reserve in Cheng County, with a protected area of 524.4 km^2, a forest coverage rate of 43.5%, eight environmental

treatment projects, two sewage treatment plants, a centralized sewage treatment rate of 32% in the urban area and two waste treatment plants.

In order to promote the construction of urban ecological civilization in Longnan area, we should pay attention to the following aspects.

(1) Strengthen publicity on environmental protection and improve residents' awareness of ecological environmental protection.

(2) The government should increase investment, strengthen the infrastructure construction of each county, increase the green area and expand the city square.

5. Conclusions

This paper selects 13 index systems of ecological civilization city construction level in 9 counties of Longnan City, establishes the index system of ecological civilization city construction level in Longnan City according to these index systems, and processes the index data by using entropy weight TOPSIS method.

Conflict of interest

The authors declare no conflict of interest.

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